Research on Reactive Power Compensation Mode and Harmonic Wave Control Technique for Submerged Arc Furnace

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Abstract

This article described the energy saving principle of submerged arc furnace as well as the advantages and disadvantages of four kinds of reactive power compensation, focusing on low voltage shunt capacitor compensation system applied in practice. It investigated harm of harmonic and proposes solutions of passive filter. This article pointed out that a reasonable selection of reactive power compensation mode and harmonic wave control, the product quality, power factor and other index can be obviously improved and enhancd, better economic benefit can be obtained.

Keywords

Submerged Arc Furnace; Reactive Power Compensation Mode; Harmonic Control

Introduction

Submerged arc furnace, also known as electric arc furnace or resistance furnace, which is mainly used in the metallurgical industry smelting ore, carbonaceous reducing agent etc.. Submerged arc furnace is an inductive load at work, it will consume a large portion of the reactive power. Submerged arc furnace is a high energy-consuming systems. In order to improve product quality, increase efficiency factor, saving energy, it should be take measure of reactive compensation. In addition, the harmonic will produce when smelting, once the generation of harmonic, harmonic current is small can be caused by harmonic current greatly, resulting in damage to the system, so some means of harmonic be taken during the reactive compensation control.

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Study of Reactive Compensation Method

The submerged arc furnace of the electrical system is mainly composed by the transformer, the short wire electrode and the weld pool. According to the working characteristics of the submerged arc furnace, submerged arc furnace consumes a lot electricity in the process of reduction smelting. General submerged arc furnace power up to several thousand kVA, even tens of thousands of kVA. Submerged arc furnace of natural power factor is lower, generally not more than 0.85. Low power factor not only lowered the efficiency of transformer, consume large amounts of it, and can also lead to three power imbalance. Reactive power also can lead to current increases, and apparent power increased, the total current, circuit and transformer voltage drop increases.

TABLE 1. COMPARISON OF THE THREE FORMS OF COMPENSATION

	High-voltage side reactive compensation	Medium-voltage side reactive compensation	**Low-voltage side reactive compensation**
Power Factor	**Improve**	**Improve**	Improve
Energy-saving	**None**	**None**	Improve
Increase production	**None**	**None**	Improve
Improve furnace ore	**None**	**None**	Improve
Improve the quality	**None**	**None**	Improve
three-phase imbalance	None	None	Improve

So, in order to effectively use electricity, we must make full use of the equipment capacity, improve their effective power.

Improve the power factor, that is, to carry on the reactive power compensation. According to the

compensation device and transformer position, at present basically has the three forms of compensation. Use a table for three under compensation form comparison:

By comparing it can be concluded that the most appropriate method is the low voltage side. Submerged arc furnace belongs to the perceptual load, which equivalent circuit can be seen as resistance R and inductance L series circuit.It can adopt method of parallel capacitor compensation, compensation system circuit model as shown in Fig. 1:

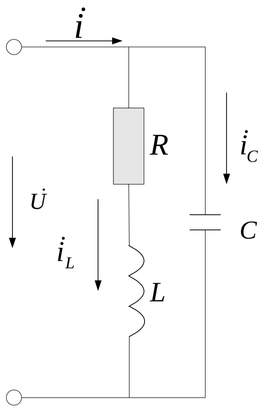

FIG.1 COMPENSATION SYSTEM CIRCUIT MODEL

The circuit's current equation:

$$\dot{I} = \dot{I}_C + \dot{I}_L \tag{1}$$

The vector is shown in Fig. 2:

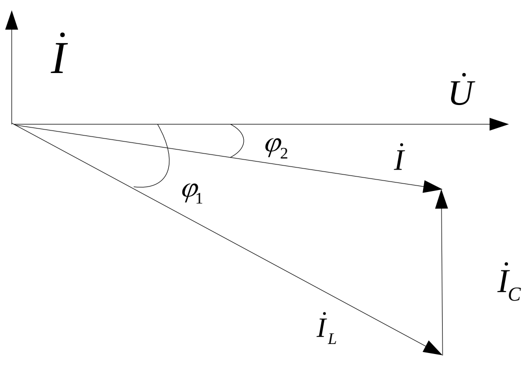

FIG. 2. THE CURRENT VECTOR OF REACTIVE POWER COMPENSATION SYSTEM

In AC circuits, the phase difference between voltage and current (Φ) cosine is called power factor. As can be seen after the parallel capacitor, phase difference between voltage and current is reduced, submerged arc furnace power factor improvement.

Reactive Power Compensation Capacity

Reactive power compensation when the first submerged arc furnace run sample tests (such as electric furnace furnace parameters, electrical parameters and overload conditions, electrode insertion depth, the daily output etc.).Analysis and calculation, based on the collected data to identify the root cause of the submerged arc furnace poor performance or for other reasons, to avoid, such as production equipment operating characteristics do not match, the production equipment operating characteristics and smelting parameters do not match.Then take reactive power compensation program in order to improve the power factor for maximum efficiency and economic benefits.

For reactive power compensation, the compensation capacity can be calculated using the following formula:

$$Q_c = P\left(\sqrt{\frac{1}{\cos^2\varphi_1}-1} - \sqrt{\frac{1}{\cos^2\varphi_2}-1}\right) \tag{2}$$

the formula, φ_1, φ_2, respectively, the power factor angle before and after compensation for the active power; P for the active power ; Q for reactive power compensation.

In general, the power factor compensation should not exceed 0.95, otherwise there will be over-compensation phenomenon, affecting the stability of the system.

Compensation capacitor is put into use, damage to internal components of the compensation capacitor is inevitable. The reasons for the compensation capacitor is damaged natural damage, over-current, over-voltage and harmonic(harmonic harm is one of the most serious). Damage to the capacitor if not timely resection, short circuit may occur, further causing an explosion, caused by peripheral equipment damage, personal injury and other serious consequences. Generally in compensation capacitor will consider to take the following measures:

(1) Over-current protection. Fuse is used as over-current protection of capacitor. When the capacitor occurs an internal short-circuit fault, it will remove the fault capacitor, so that the other normal capacitor intact, to maintain the normal operation of the capacitor Banks. Each capacitor should have a separate fuse protection. The fuse current can be 1.5 to 2.5 times the rated current selection

(2) Over-voltage protection. Installation of zinc oxide surge arresters can absorb transient over-voltage operation. Zinc oxide surge arresters in the normal

operating voltage, with a great deal of resistance, showing the insulating state, in the case of over-voltage, showing a low-resistance state, the release current, the electrical equipment in parallel with the arrester residual voltage limited to a safe value below the device; the reduced overvoltage arrester rapid recovery of high-resistance, this time showing the insulated state, thereby effectively protecting the capacitor bank to be exempted overvoltage damage.

(3) Set up a special discharge device. Capacitor belongs to the energy storage element, when the capacitor is disconnected from the power source, a capacitor voltage poles still exist, and the initial value is equal to the voltage circuit disconnection when the moment of power supply voltage.

For low voltage power grid reactive power compensation device design with white indicator lamp (ac 380 v, resistive) constitute a capacitor discharge loop, and may direct the capacitor discharge status and operation.

Harmonic Control

The electric power system is typically defined as the harmonic contained in the current of integer times to fundamental wave frequency power. Symmetry three-phase power system harmonic is usually an odd number: 3 times, 5 times, 7 times, 9 times... And with the increase of the harmonic number of the order of magnitude decrease. Harmonic constitute the main distortion of the supply voltage and load current waveform,the greater the harmonic content, the greater the degree of distortion.

The harm of harmonic is shown in table 2:

Because passive filter has a low cost, high reliability, as well as to protect the operational characteristics of the device, here we adopt the method of passive filter for harmonic governance. Fig. 3 is a typical passive filter schematic. The *LC* circuit and power supply equipment installed in parallel for every harmonic filtering. One caused by harmonic resonant circuit, actually correspond to the frequency of harmonic current caused by short circuit, the frequency of harmonic current in theory all flow into the filter without injected into power grid, to achieve the purpose of filtering. The bypass circuit absorption of harmonic, thereby avoiding harmonics into the power distribution network. The passive harmonic in parallel in the circuit, no power.

TABLE 2. THE HARM OF HARMONIC

Phenomenon	Consequence	Reason
Overheating of the transformer	Shortening the transformer life and reduces the effective capacity of the transformer.	The high frequency current-generating larger copper loss and iron loss.
Zero line current is too large	Cable accelerated aging, and even induce fire.	Various types of electrical equipment produced by single-phase harmonic superimposed on the zero line, the current effective value close to 1.7 times the phase line.
Reactive power compensation capacitor overcurrent	Capacitance is overheating or even damaged, the harmonic amplification.	The capacitive reactance of capacitor is inversely proportional to the frequency, the harmonic current waveform distortion is very high.
Protection equipment misoperation	Accidentally tripped and power outages	Protection equipment is in accordance with the design and calibration of the sinusoidal voltage and current.

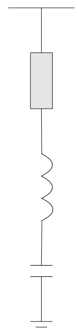

FIG. 3. THE MODEL OF PASSIVE FILTER CIRCUIT

The filter parameters satisfy the formula (3) and (4):

$$\frac{1}{n\omega C} = n\omega L \tag{3}$$

$$Q = \frac{U^2}{\frac{1}{\omega C} - \omega L} \tag{4}$$

$$C = \frac{n^2 - 1}{n^2} \cdot \frac{Q}{\omega U^2} \tag{5}$$

$$L = \frac{1}{n^2 \omega^2 C} \tag{6}$$

Wherein, n is the harmonic number, and w for the electrical angle frequency, Q for the compensation of reactive power, U for the rms value of the grid voltage, C is the filter capacitor, L is the filter inductor. Formula

(5) and (6) come from the simultaneous solution of formula (3) and (4) .

Conclusion

The reasonable low compensation and harmonic control program is to ensure that low-voltage compensation device security long-term stable operation. Today's establishments are striving to build a conservation-oriented enterprises. When submerged arc furnace's natural power factor below standard and need to select the low-voltage compensation ,it must be the first that field test, data analysis. Then it can take appropriate reactive power compensation and harmonic control program. In this way establishments can improve product quality, increase production and reduce power consumption, achieve the purpose of submerged arc furnace's energy saving , also can better satisfy establishments high efficiency, energy saving and environmental protection requirements.

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